Validation of CERES-MODIS Arctic cloud properties using both ARM and CloudSat/Calipso Observations

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Goals of this study

1. To compare cloud bases and tops derived from ARM and CloudSat/ Calipso observations over the ARM NSA site.
2. Then to compare cloud microphysical properties derived from ARM and CloudSat/Calipso with CERES-MODIS retrievals.
3. Finally we will compare CloudSat/ Calipso results with CERES-MODIS retrievals over entire Arctic and Antarctic regions in next couple years.

DOE ARM NSA Measurements

Hbase: Cloud-base height determined by MMCR/ceilometer/lidar

Htop: Cloud-top height determined by MMCR (45 m)

Reflectivity: MMCR ARSCL

Liquid water path: Microwave radiometer

All results are averaged over 1-hr period centered at CloudSat/Calipso overpass

Satellite measurements/retrievals

- **CloudSat/Calipso (CC): (Results from CSU)**

Level 2B data products, averages over a 1^{o}x1^{o} grid box

Hbase/Htop heights: determined by both 94 GHz radar and Lidar with a vertical resolution of 240 m.

Liquid/ice particle sizes and contents/paths: retrieved from 94 GHz radar (Radar only, works for both day and night time with higher uncertainty than radar+ visible optical depth)

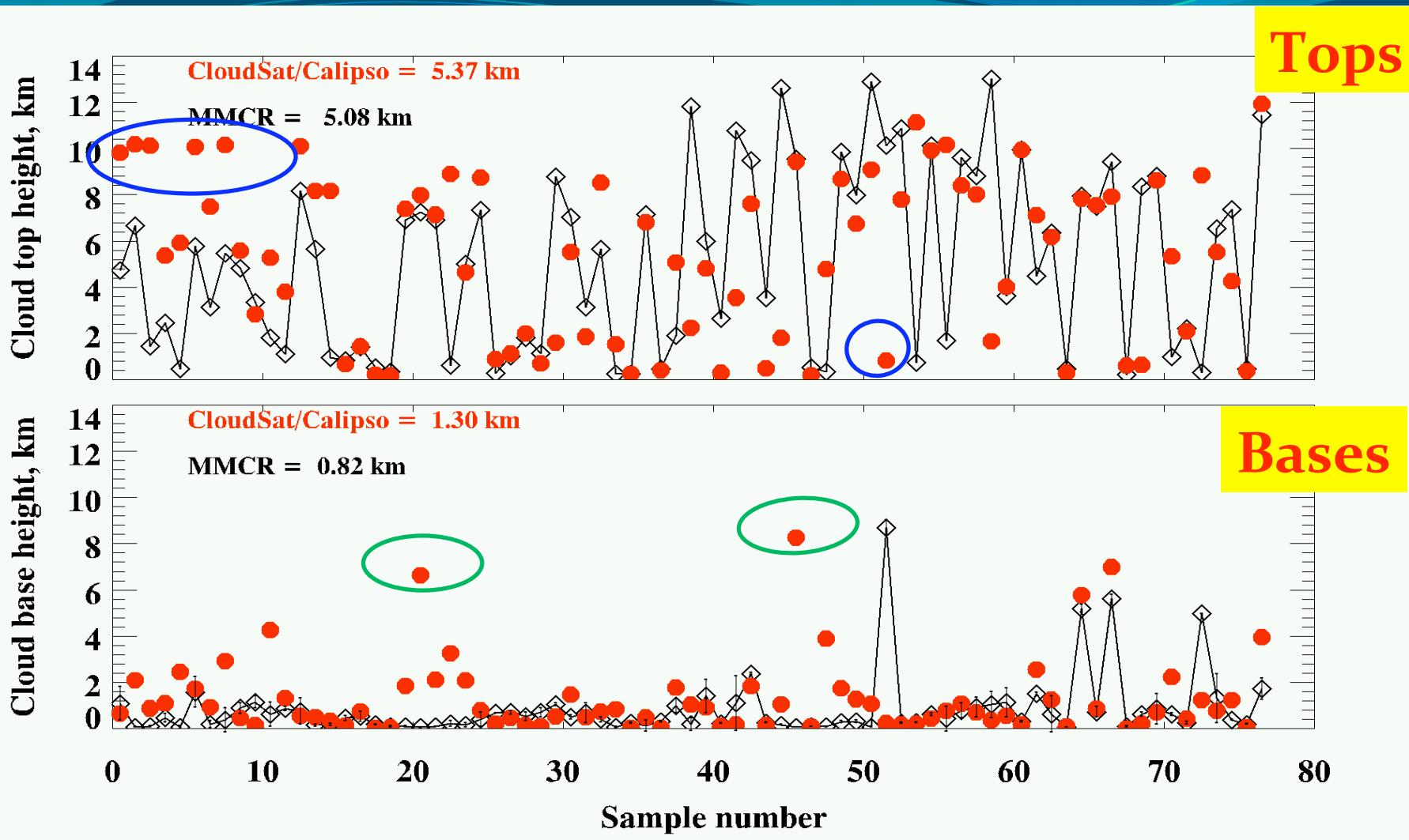
- **CERES/MODIS data (From Minnis's group)**

  Retrieved liquid/ice cloud tops from four different layers

  Liquid/ice particle sizes and water paths

  30 x 30 km^2 centered at NSA site

Matched cases between ARM and CC (05/2006-04/2009)

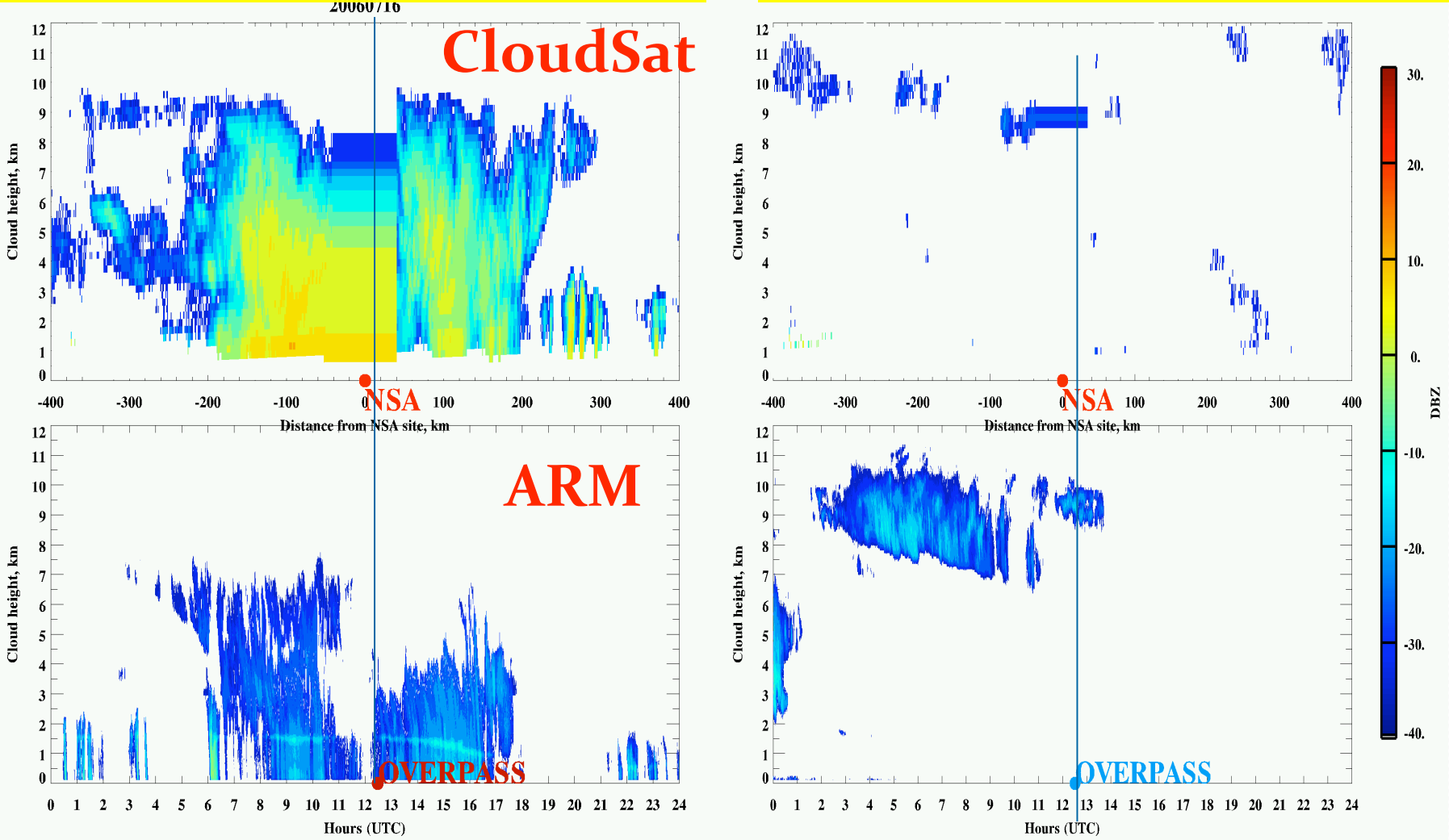


Although their average differences are within 0.3-0.5 km in cloud top and base comparisons, some large differences exist which motivates us to investigate:
Cloud tops: Cases 3 and 52; Cloud bases: Cases 20 and 46

Cloud-top comparison

Case 3: (CC=10, ARM=1.5)

Case 52: CC=1, ARM=10)

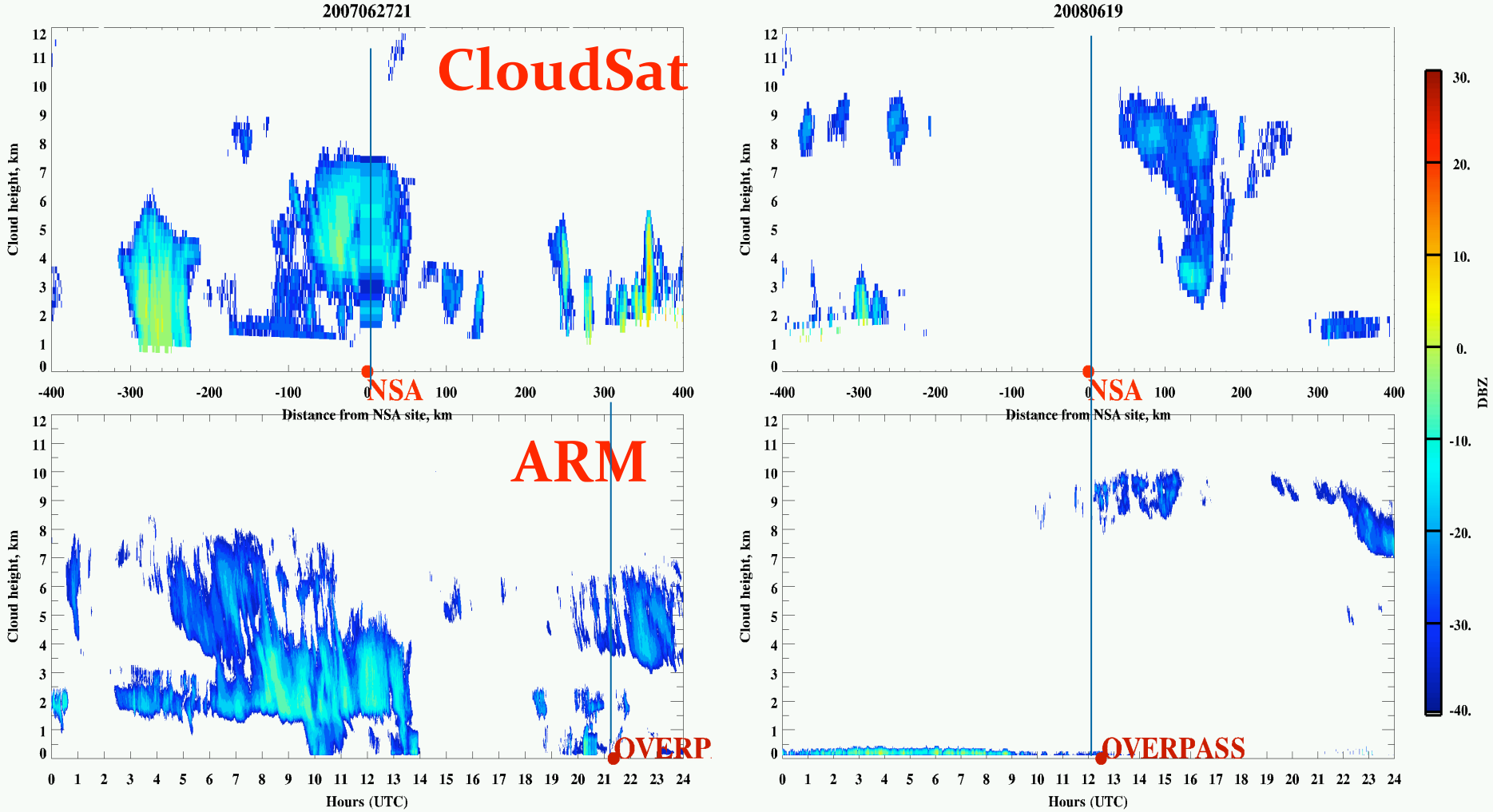


CloudSat is about 20 km away from the ARM NSA site

Cloud-base comparison

Case 20: (CC=7, ARM=0.5)

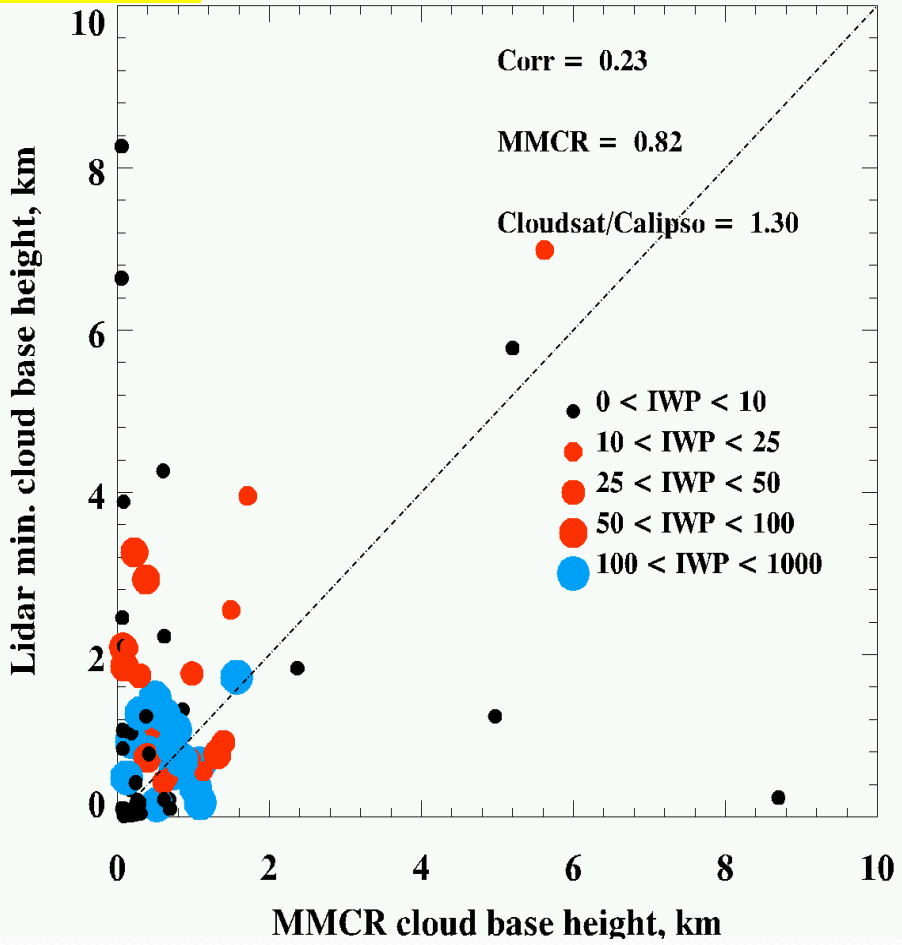
Case 46: (CC=8.5, ARM=0.5)



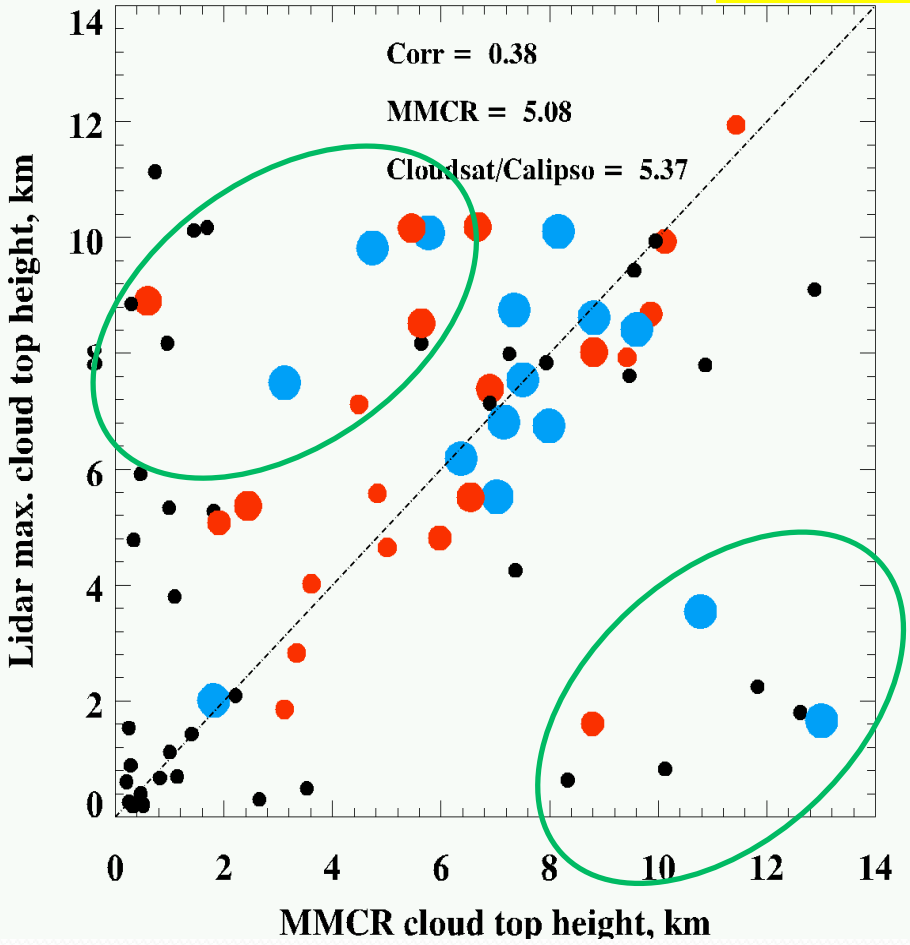
The cloud bases near the surface are beyond the limit of CloudSat

Comparison of cloud heights between ARM and CC

Bases

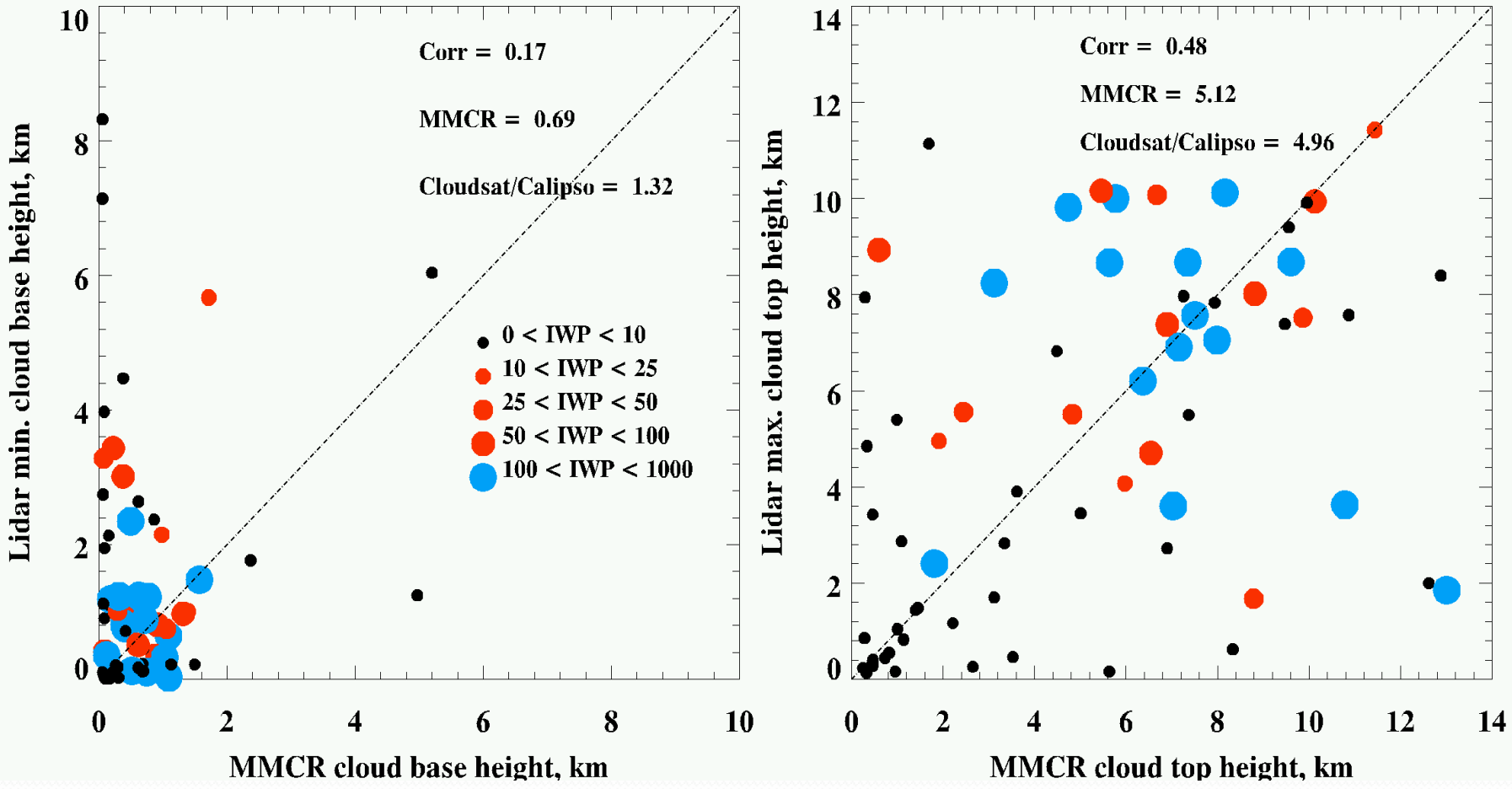


Tops



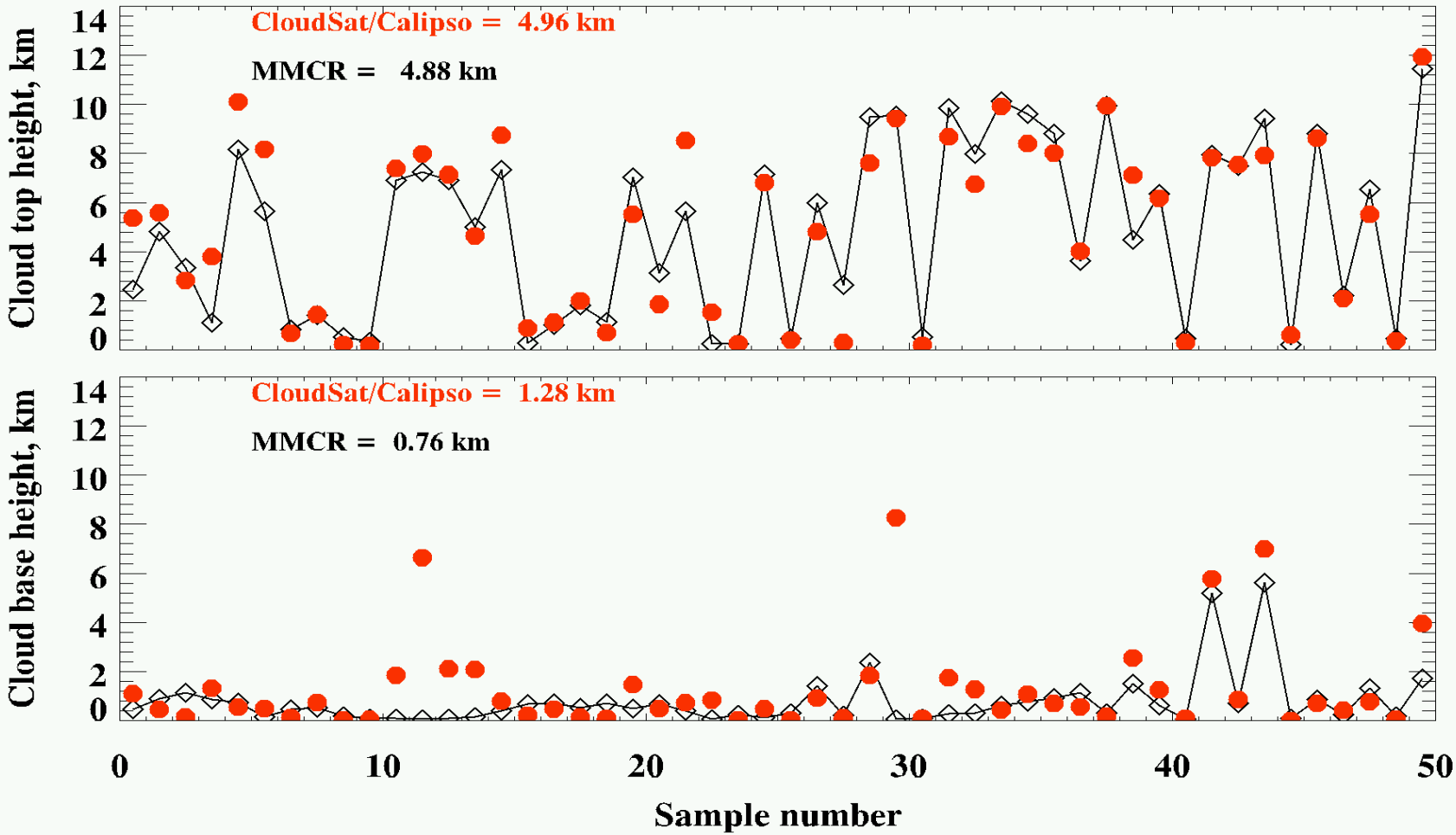
The CC derived cloud bases and tops have NO relationships with IWP

0.5 □x0.5 □ CloudSat/Calipso vs. 1-hour ARM



Changing spatial resolution does not improve the comparison too much

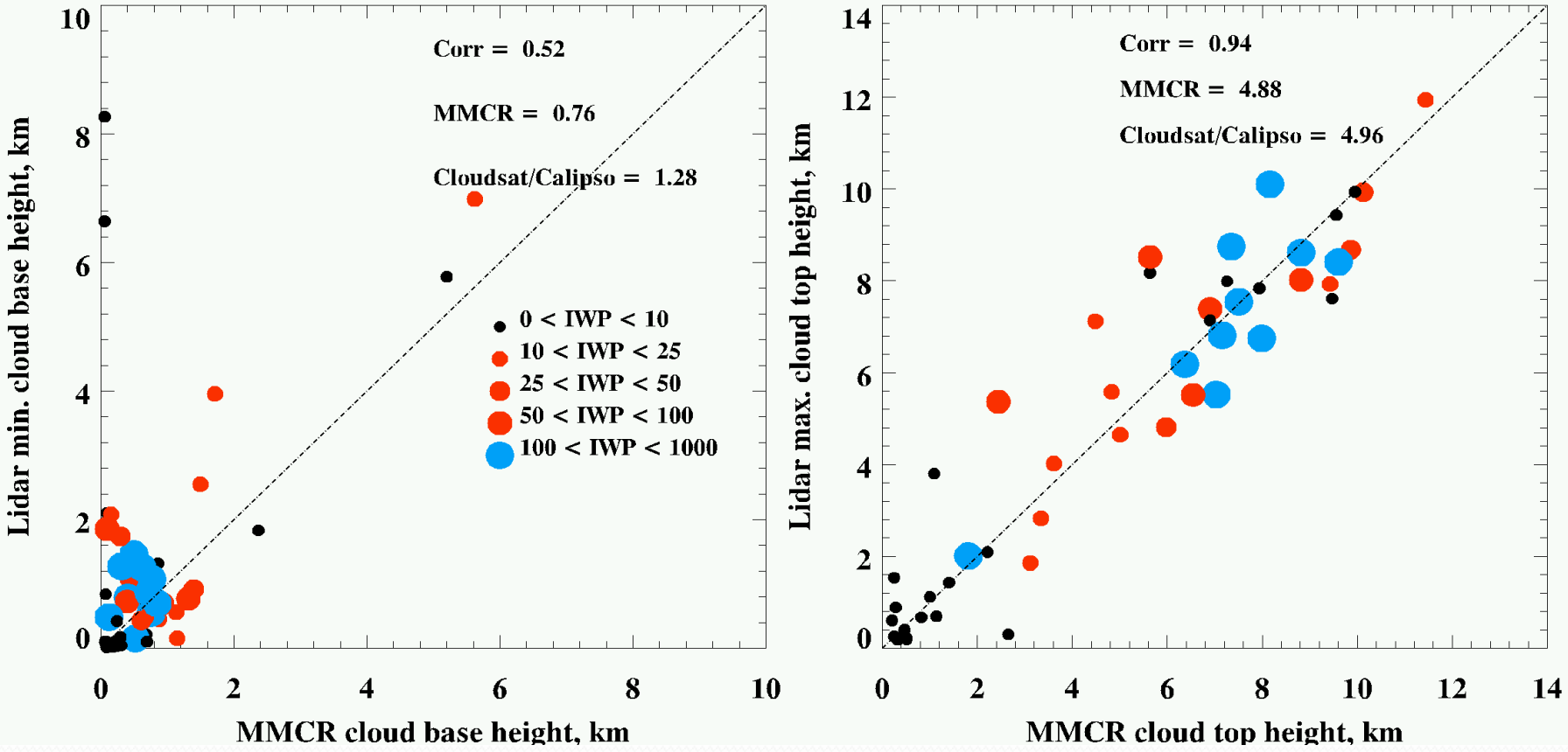
|Ztop(MMCR)-Ztop(CloudSat)| ≤ 3 km



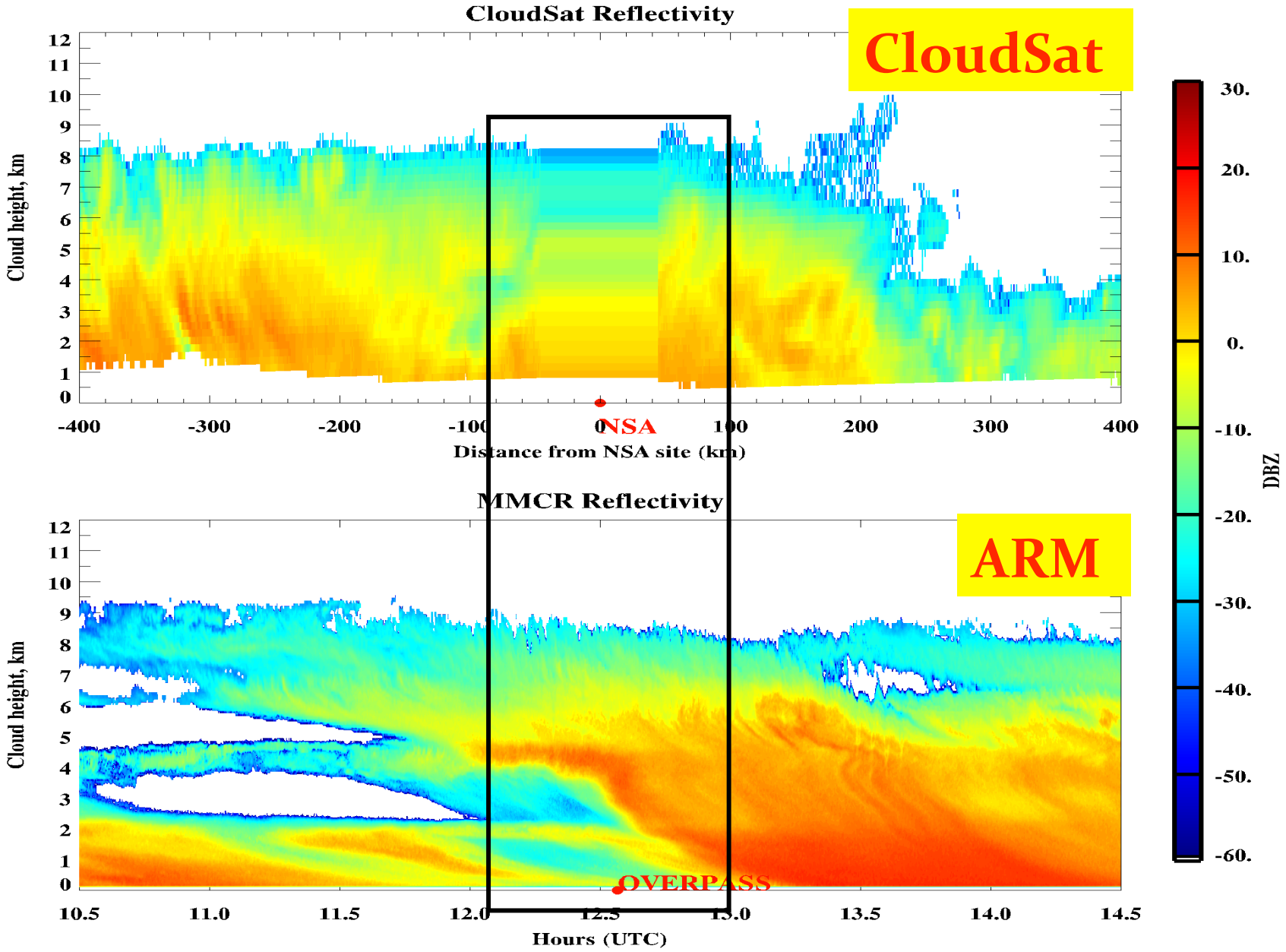
To reduce the spatial mismatches, we re-select the cases with ΔZtop < 3 km.

➔ Improve the cloud-top comparison a lot, but not much to cloud base.

Cloud-top difference ≤ 3 km

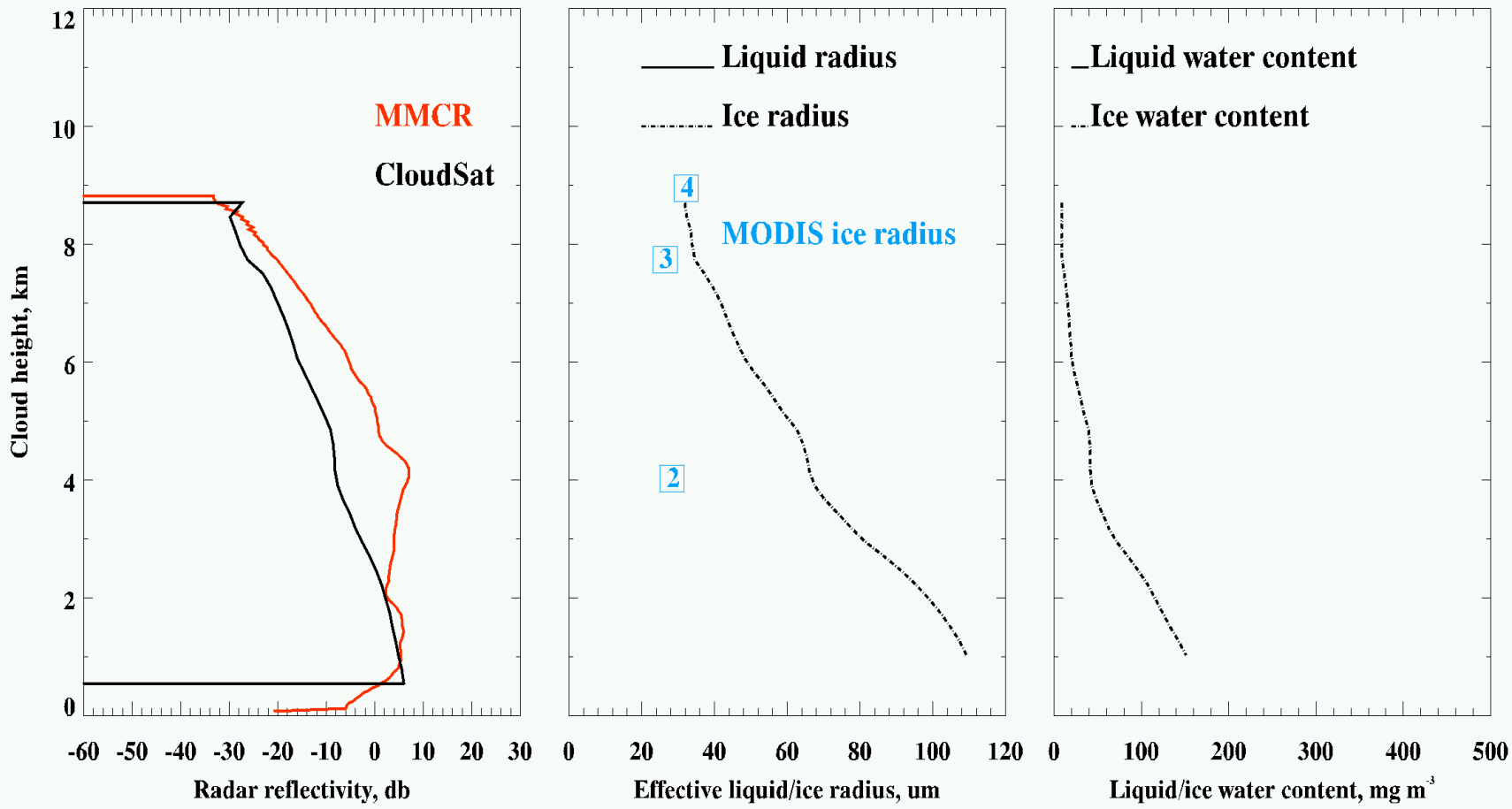


Selected uniform cloud tops can partially resolve the sampling issue.
Both satellite and MMCR can 'see' the same clouds. However the cloud-base difference still remains 0.5 km.
Both correlations increase a lot (Base: 0.23➔0.52; Top: 0.38➔0.94).



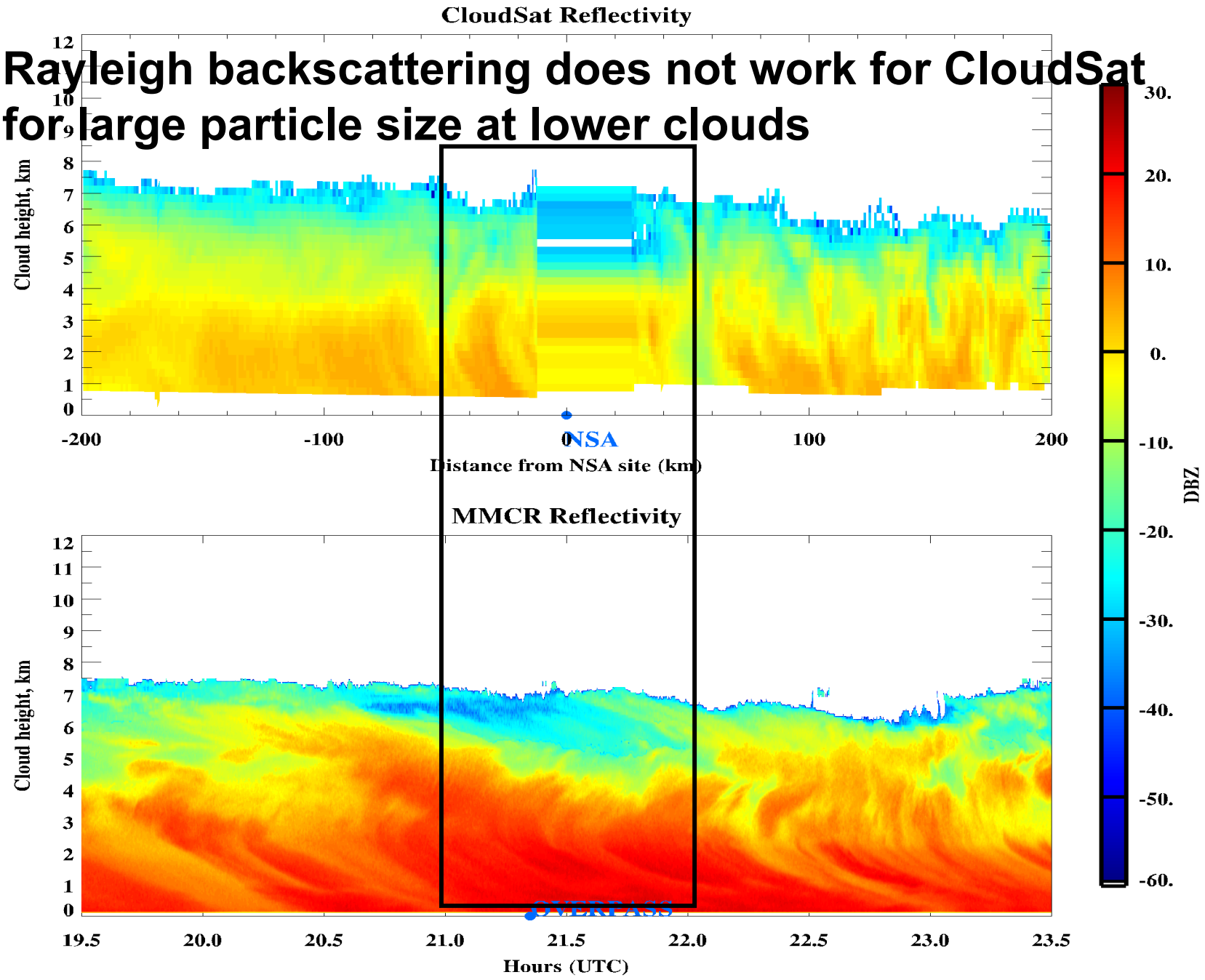
ARM MMCR reflectivity > CloudSat Reflectivity

Case 1: 02/14/2009 (cont')

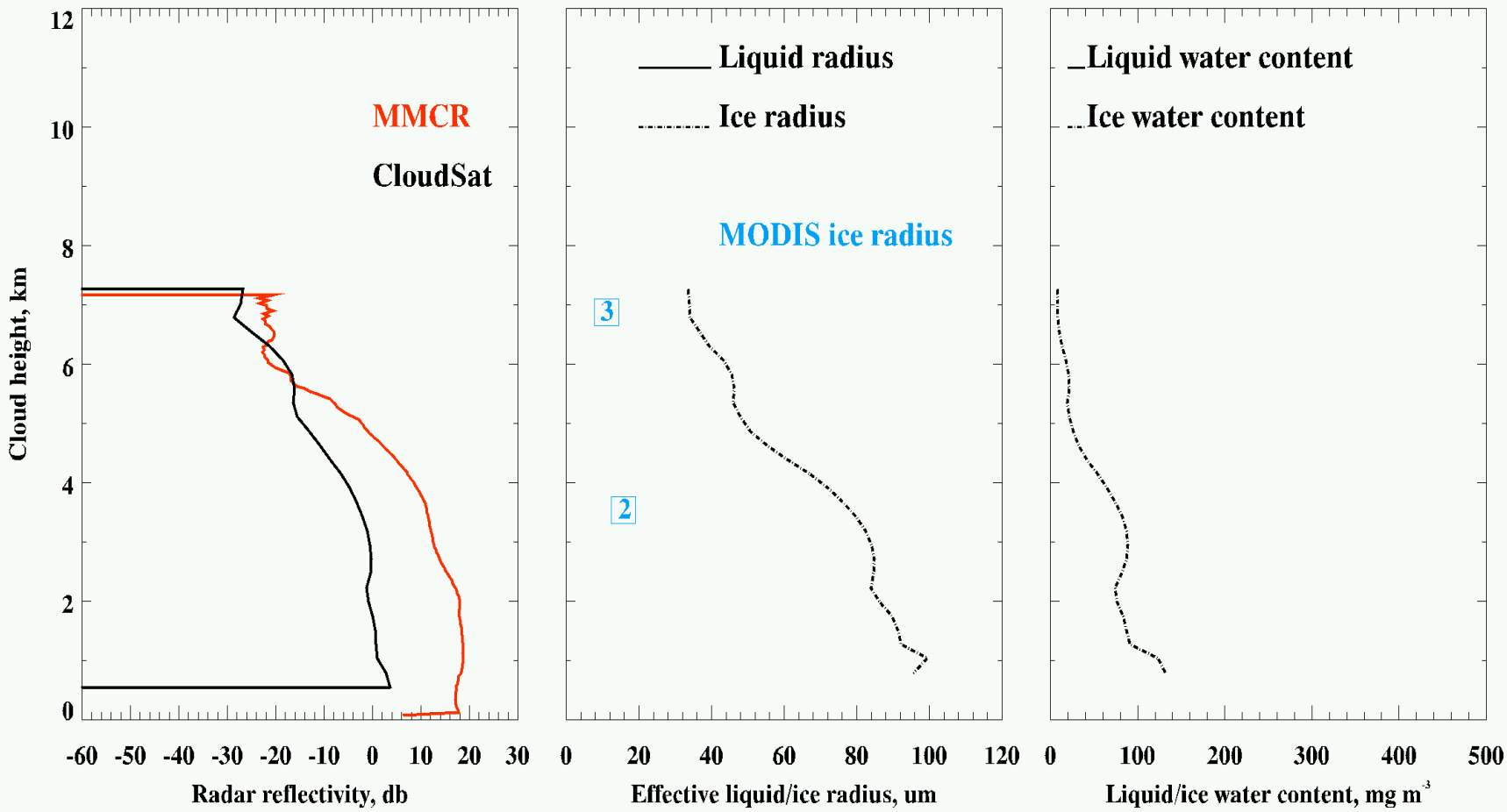


MODIS-retrieved ice particle size at layer 4 agrees well with CloudSat retrievals, but under estimated at layers 2 and 3.

Rayleigh backscattering does not work for CloudSat for large particle size at lower clouds

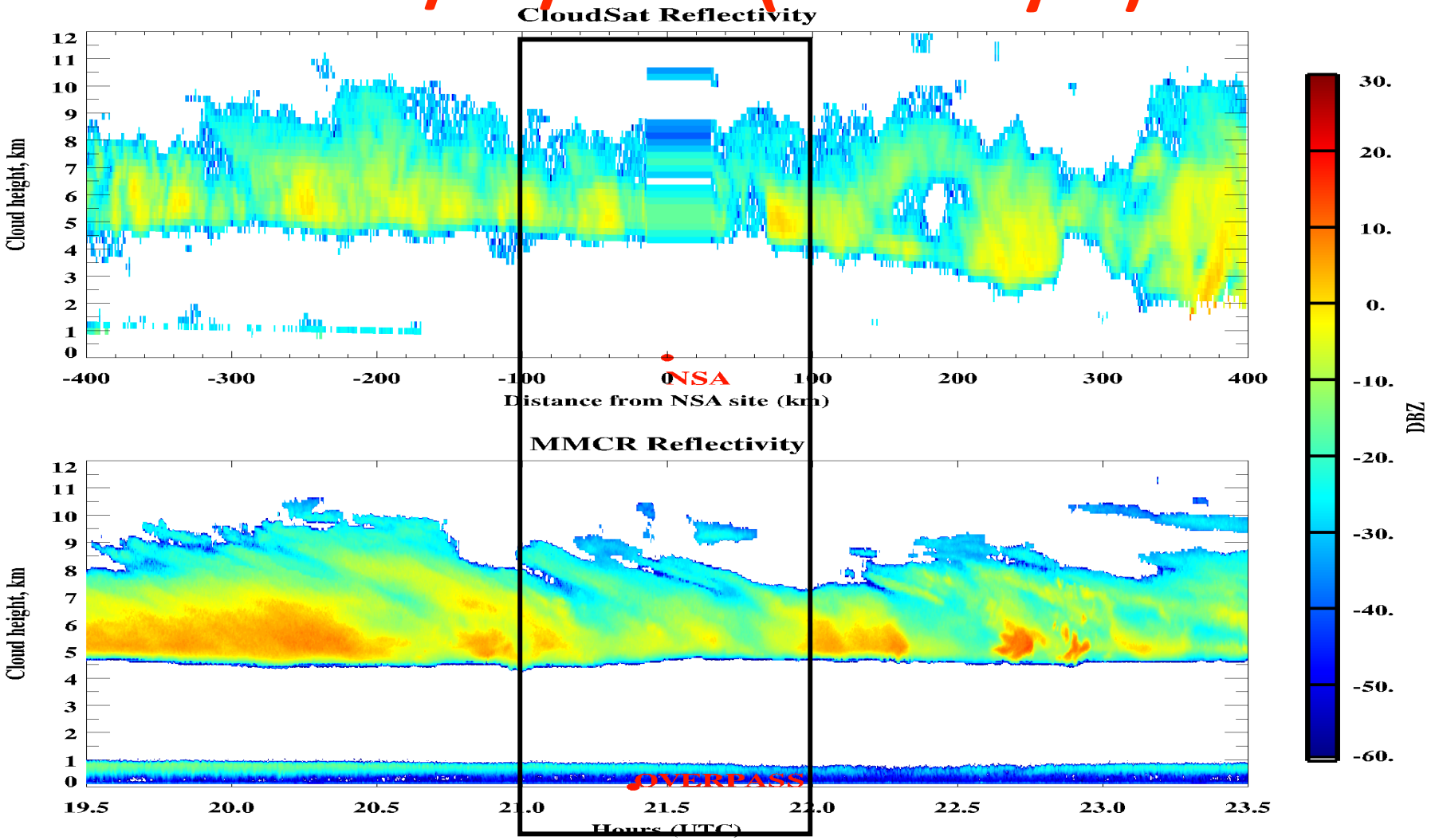


Case 2: 02/22/2008 (cont')



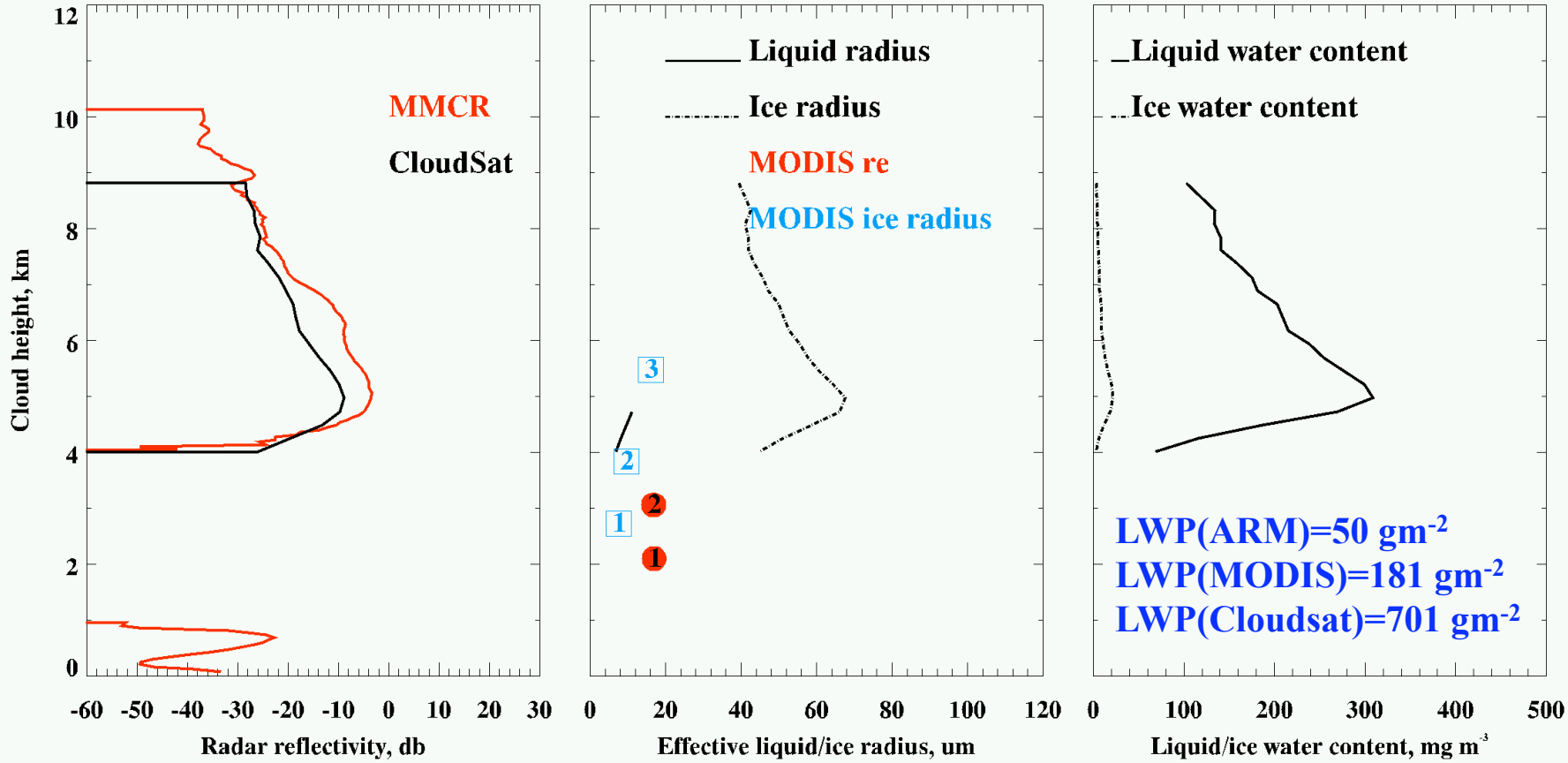
MODIS-retrieved ice particle size at layers 2 and 3 are much smaller than CloudSat retrievals

Case 3: 09/17/2008 (Multilayer)



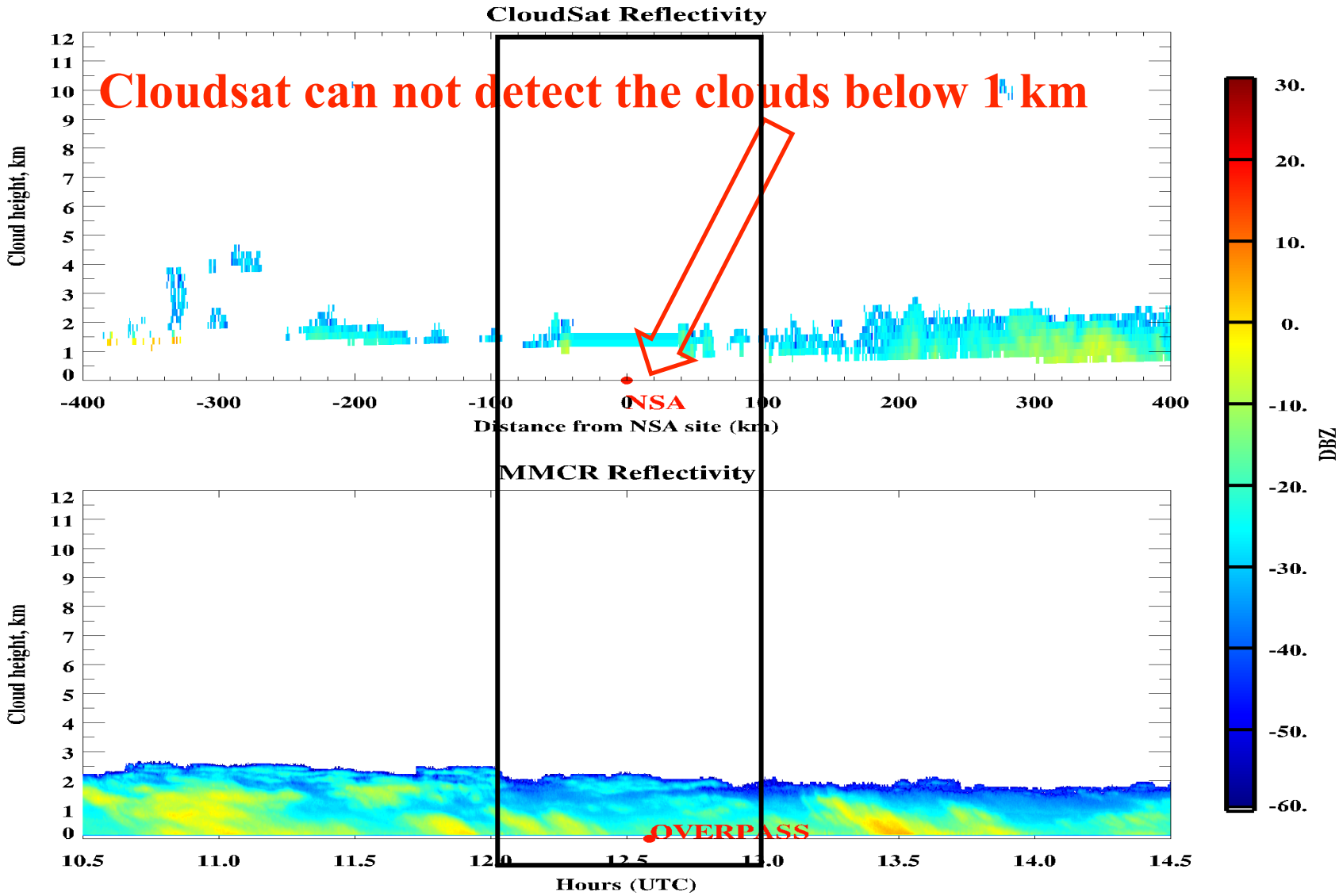
Perfect agreement in upper layer clouds, but CloudSat can not detect the clouds below 1 km.

Case 3: 09/17/2008 (Cont')

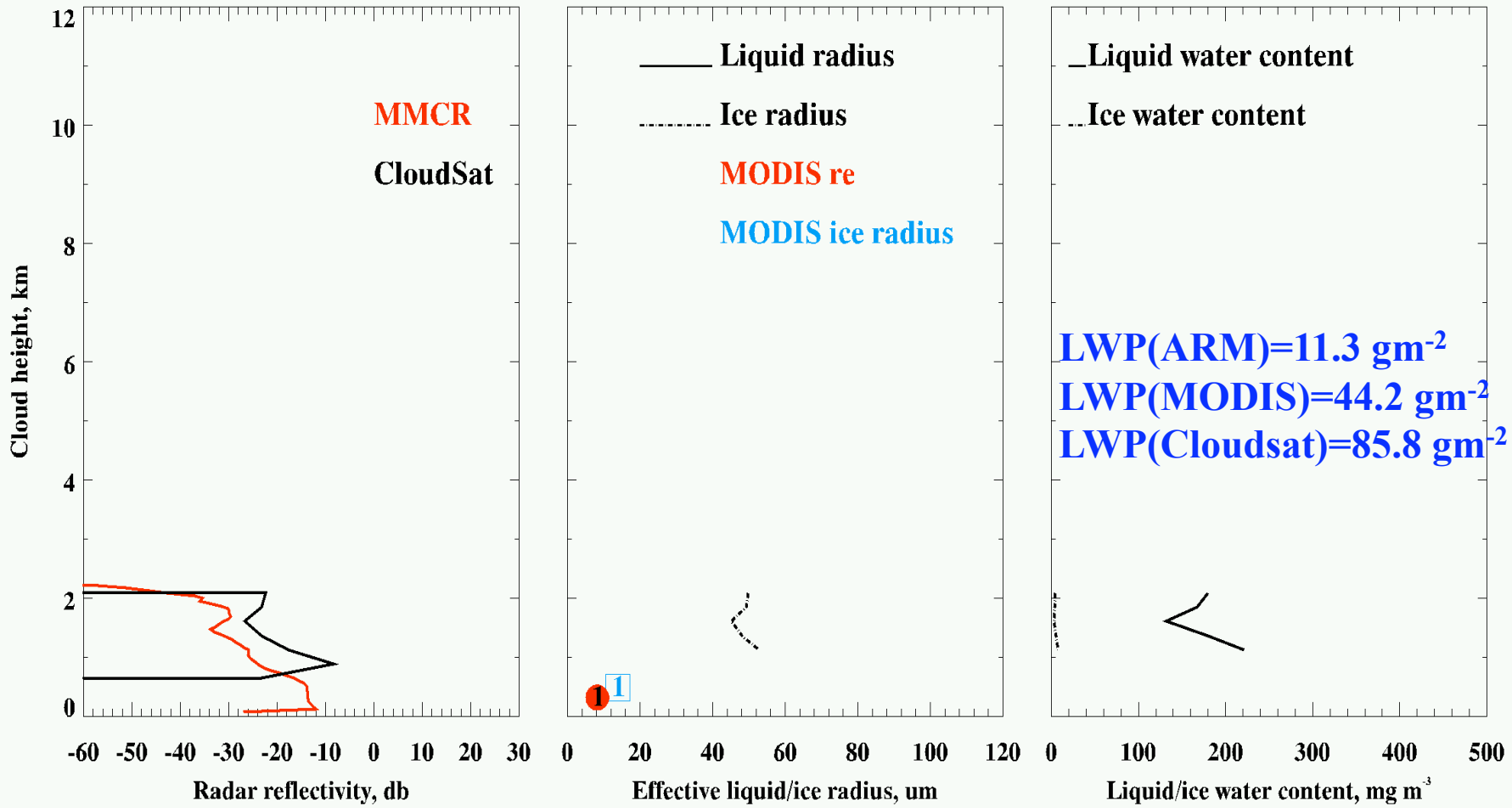


MODIS liquid re values agree with CC, but ice re are much smaller. LWP derived from CC is much larger than MODIS and ARM

Case 4: 03/18/2009 (low-level stratus)



Case 4: 03/18/2009 (cont')



Conclusions

1) **Cloud base/top and reflectivity from CC and ARM:**

➔**The cloud-top difference between CloudSat/Calipso and ARM radar is ~300 meters for all the samples in $1^o x 1^o$ box and 1-hour averages.**

However, this differences can be reduced to 80 meters by selecting 65% of samples ($\Delta Ztop < 3$ km), and the correlation coef. can be as high as 0.94

➔**The cloud-base difference is ~ 500 meters.**

➔**The CloudSat reflectivity is close to or slightly lower than ARM MMCR reflectivity.**

Conclusions (Cont')

2) Cloud microphysical comparison between ARM, CC, and MODIS:

➔The MODIS retrieved particle size agree well with CloudSat retrievals at upper layer, but much smaller at lower layers.

➔ CloudSat retrieved LWP >> MODIS > ARM

More case study and statistical comparison are warranted in the future work.


Thanks for your attention

CloudSat/CALIPSO (CC)

- Part of A-train constellation of satellites
  - Trails Aqua by one minute
- CloudSat: On-board 94 GHz cloud profiling radar
  - Obtains cloud profile information in addition to cloud microphysical properties
  - 1.7 km along-track resolution by 1.4 km cross-track resolution
- CALIPSO: On-board Cloud Aerosol Lidar
  - Operates at 532 and 1064 nm
  - 100 m footprint
  - 333 m horizontal resolution
  - 30-60 m vertical resolution

RTM calculated difference due to the frequency difference between two radars

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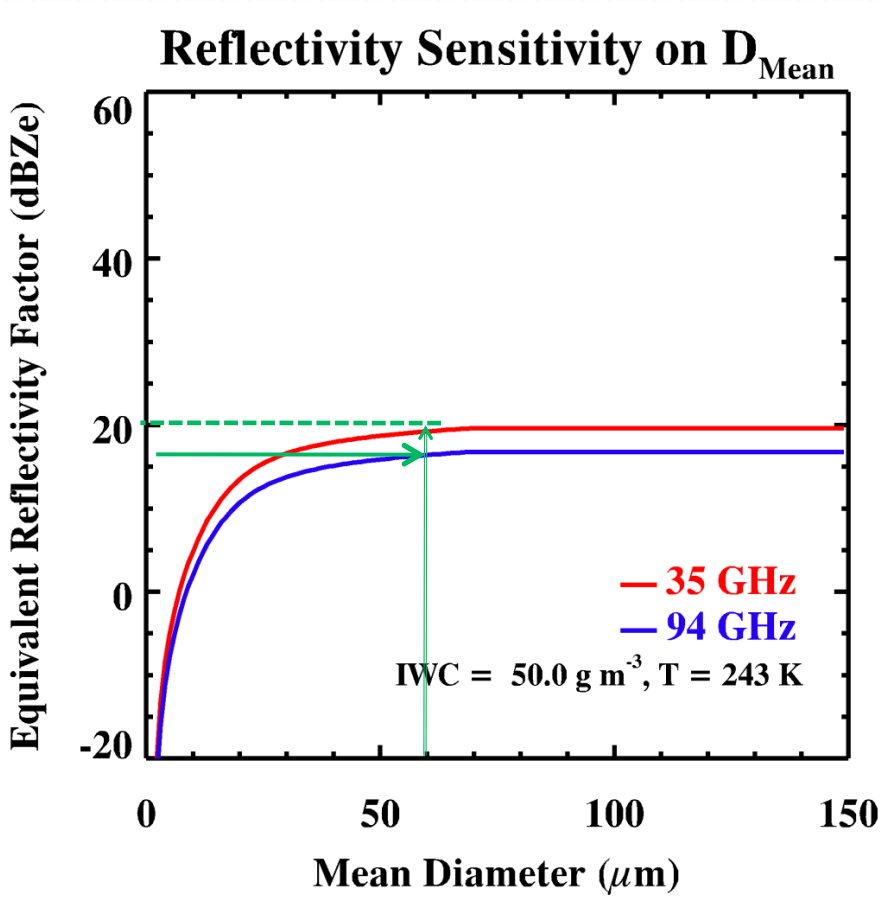
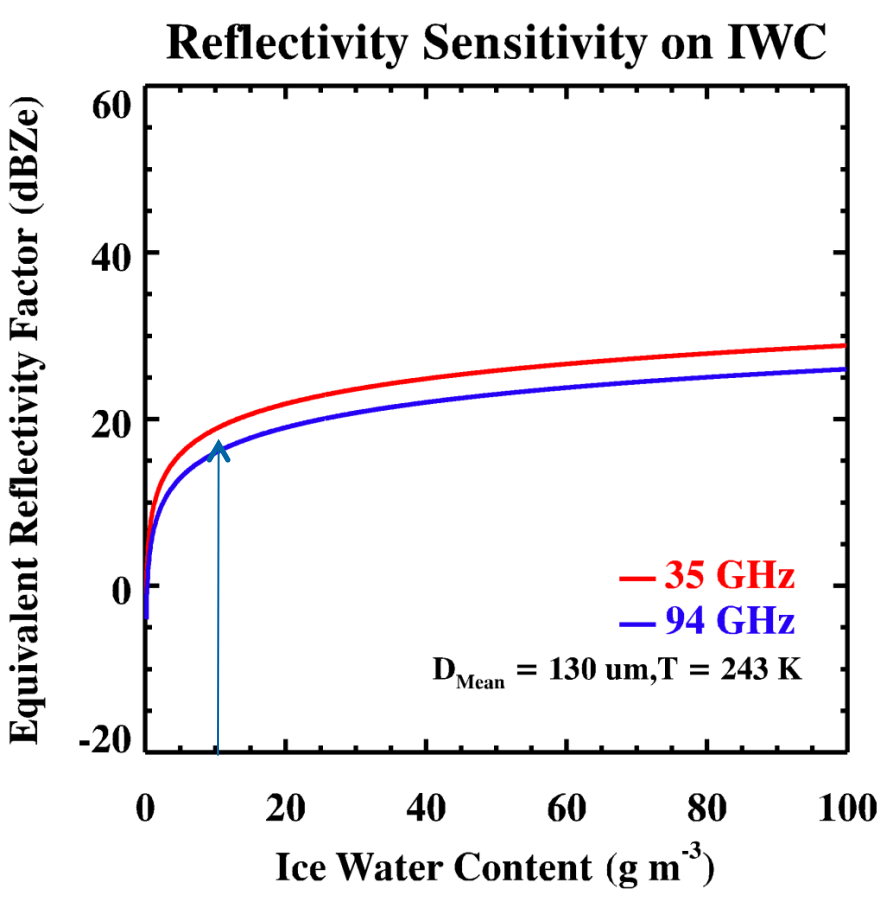
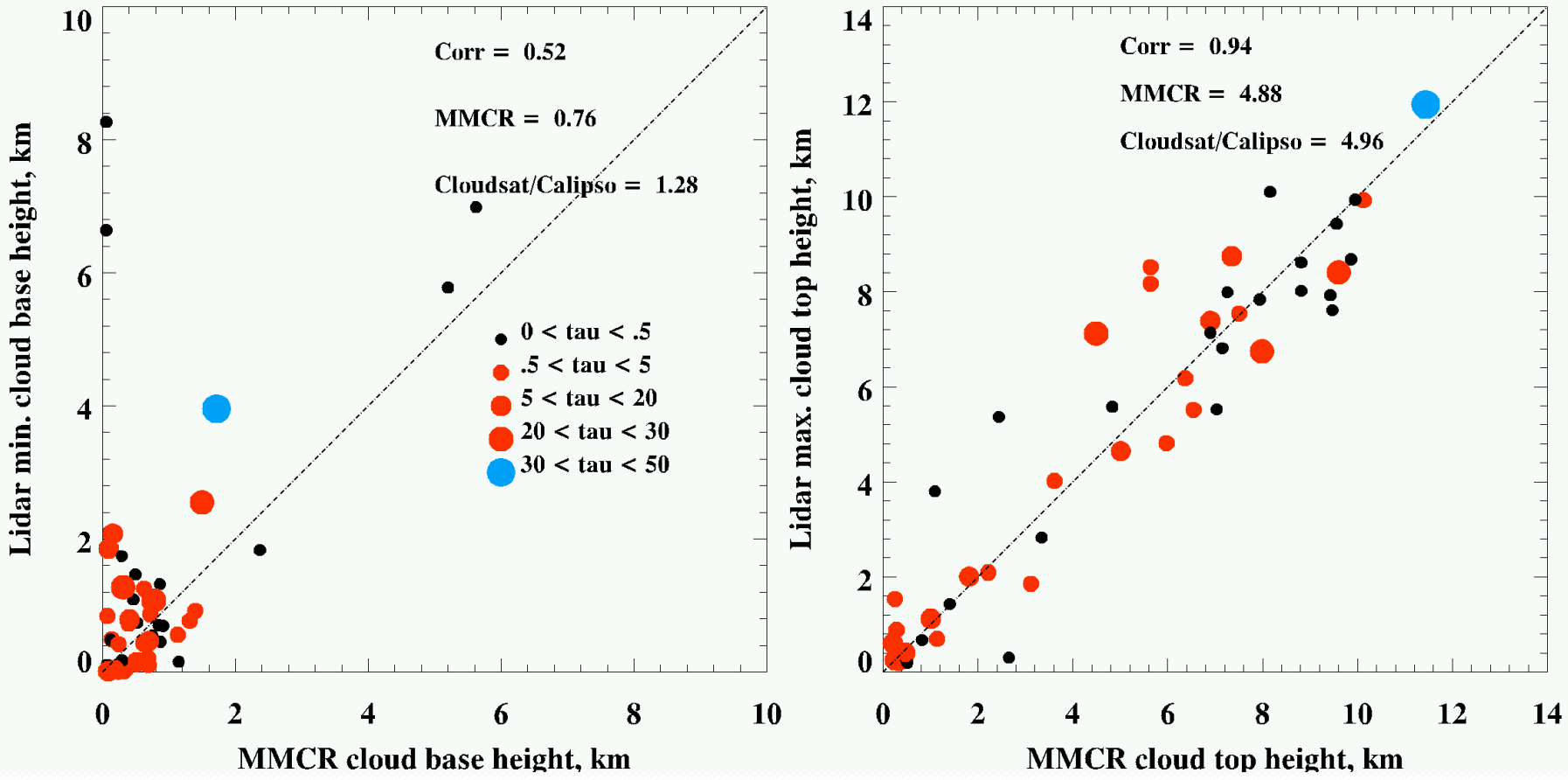


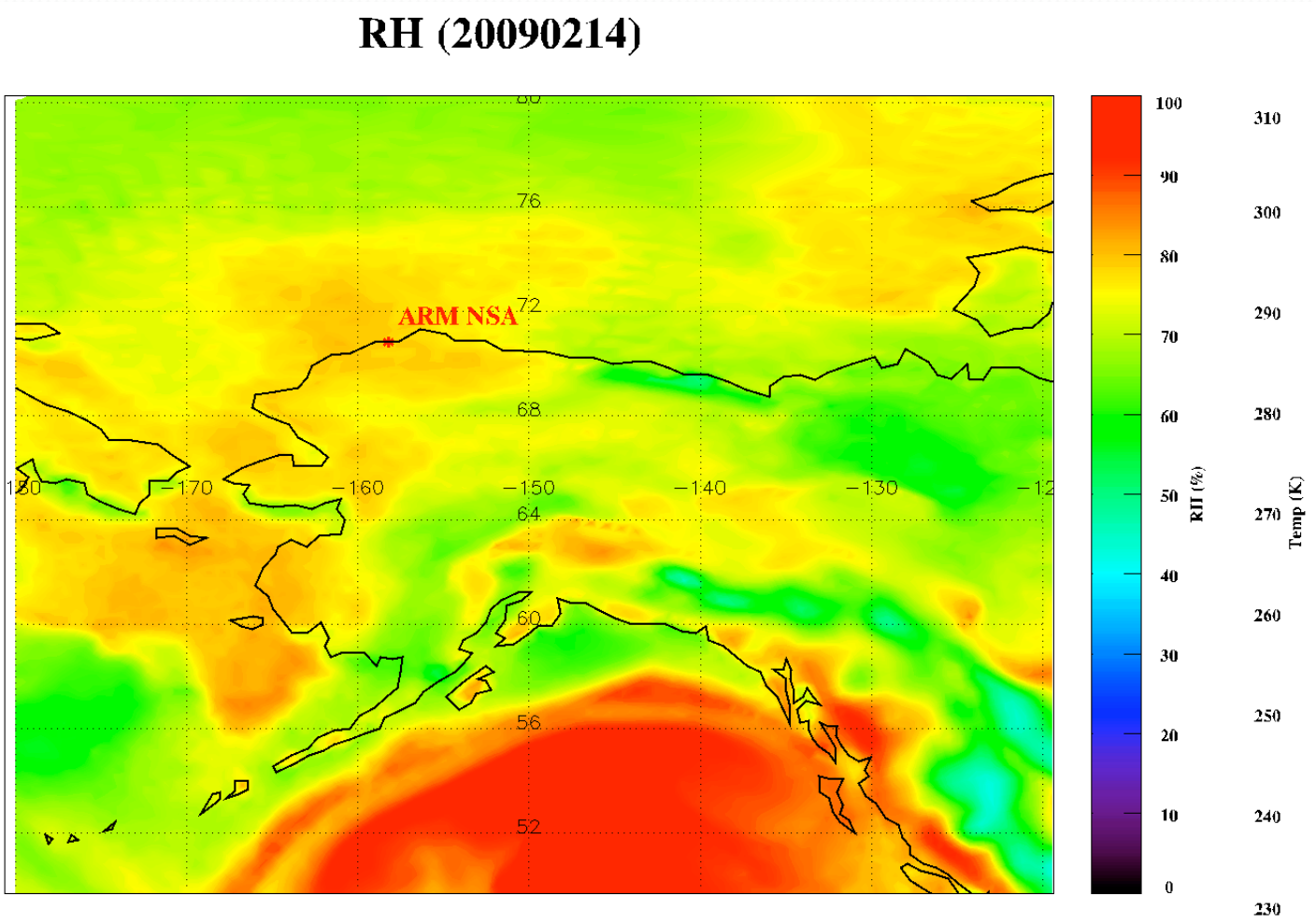


Even two radars see the same particles the absolute reflectivity difference can be ~5 db

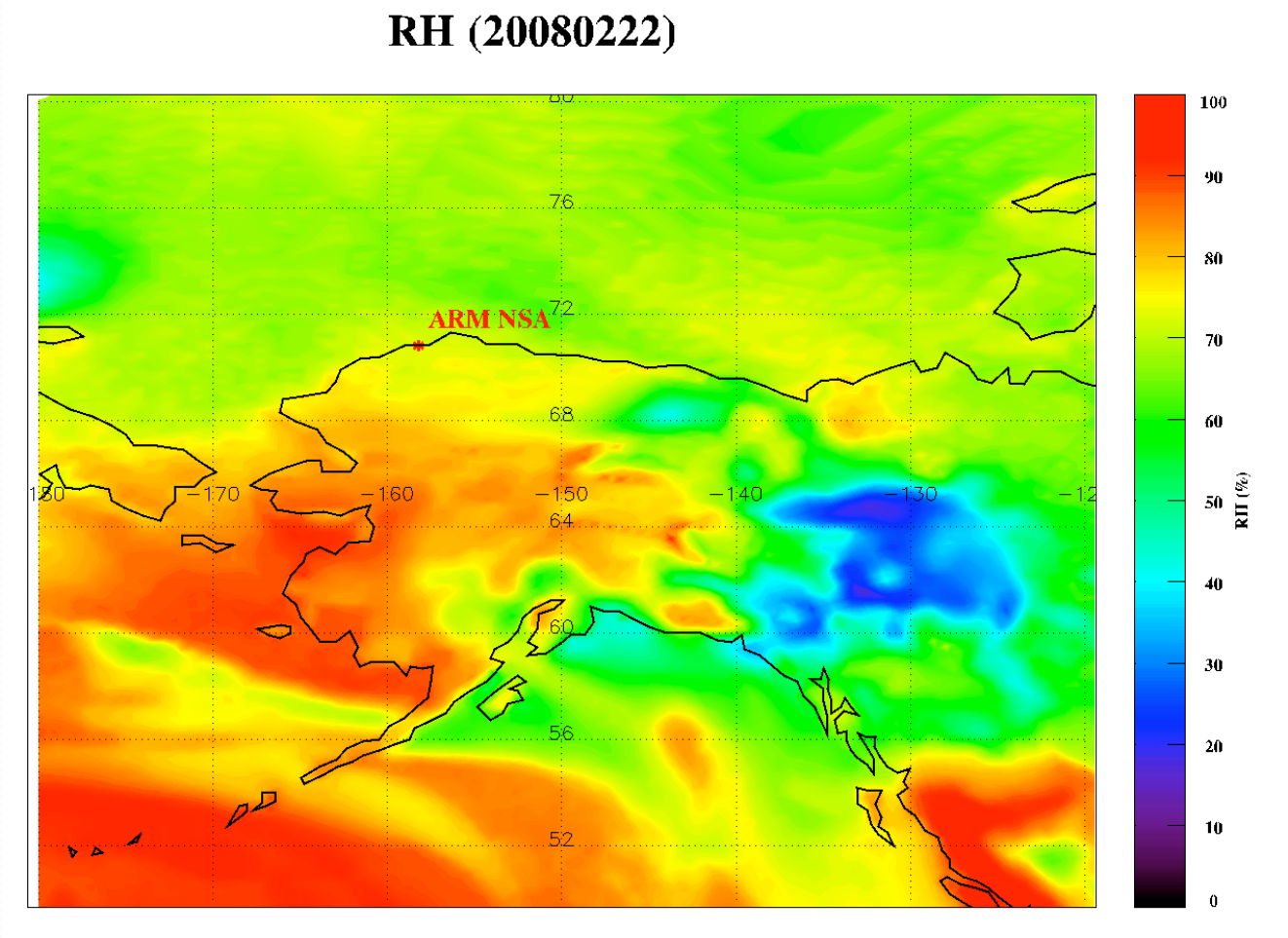
Selected samples vary with Tau



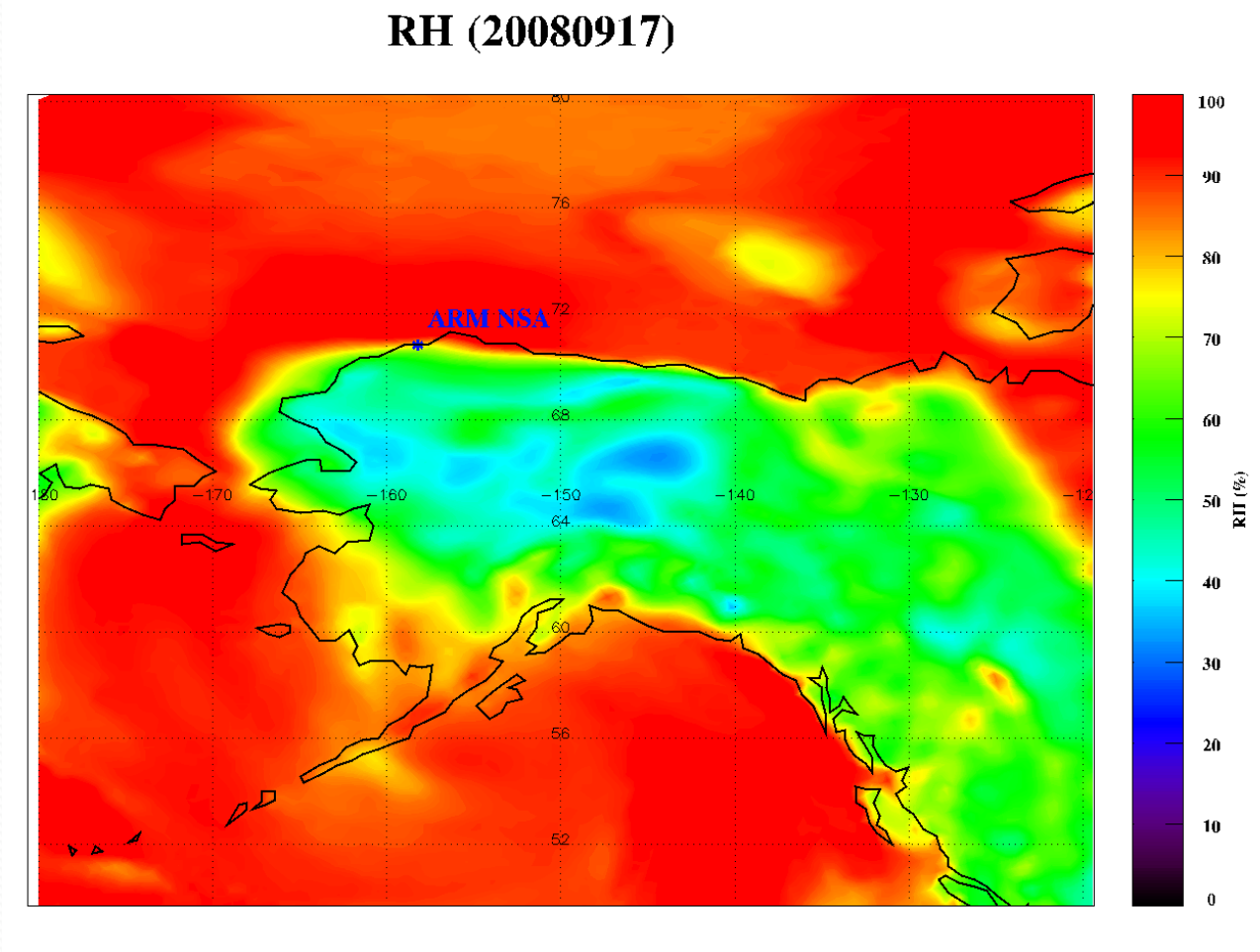
Pure Ice Cloud at Night



Pure Ice Cloud at Night



Multilayer Case



Stratus Case